# LED bulb lamps technical specification and testing procedure for solar home systems.

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**Abstract**

With the consolidation of the new solid state lighting LEDs devices, testing the compliance of lamps based on this technology for Solar Home Systems (SHS) have been analyzed. The definition of the laboratory procedures to be used with final products is a necessary step in order to be able to assure the quality of the lamps prior to be installed [1]. As well as with CFL technology, particular attention has been given to simplicity and technical affordability in order to facilitate the implementation of the test with basic and simple laboratory tools even on the same SHS electrification program locations. The block of test procedures has been applied to a set of 14 low-cost lamps. They apply to lamp resistance, reliability and performance under normal, extreme and abnormal operating conditions as a simple but complete quality meter tool of any LED bulb.

## 1.- Introduction

LED systems has introduced a new way of light generation from an electronic source which is overpassing traditional barriers of light generation efficiency and endurance and reliability [2], being a promising opportunity in the SHS field. As this process is being developed it is necessary to define and develop the necessary procedures to test and evaluate the work generated.

As a starting point, there are current international standards related to the LED technology about its luminance, lifetime and degradation over time. However it requires very high time consuming procedures involving expensive tools.

Because of this, along with the Universal Technical Standard for Solar Home System (UTSfSHS) [3], and considering the particular nature and the large number of different lamps based on the LED technology, this paper proposes a technical specification for this kind of lamps when used in decentralized PV rural applications together with its corresponding quality control procedures. Both, technical specifications and quality control procedures have been developed taking into account the constraints of the countries where decentralized PV rural electrification programs are carried out.

## 2.- Evolution from CFL to LED in SHS

While CFL provide well-known and useful devices, they may offer less efficiency and reliability than LEDs. Besides, they are less environmental friendly as the new technology does not required of lead, mercury or any other dangerous substance and they are easy to recycle.

The main disadvantage of LEDs devices was their high cost, but as the technology get more and more established these are falling down to the point they are a real option in SHS projects. However the real market situation offers a wide variety of devices, with prices that may vary highly between models and manufacturers and technical specifications that are not usually well-defined.

The lack of an international standard on LED lighting devices leaves the specifications on the LED devices [4]. However, many problems are still to be solved:

- Not all the LED manufactures complete the test indicated in these standards
- The way the LEDs are powered and the working temperature is handled may change dramatically the efficiency and the reliability of the devices
- The manufactures may not use the best LED devices or follow proper manufacturing process as they assembly their products

For all these reasons, it may be difficult to discern the quality of the devices to be used on SHS projects.

Technical specifications and testing procedures have been analyzed, defined and questioned after their first results obtained on a wide-ranging test program on a representative collection of 14 different models of 12V LED bulbs acquired in the current SHS market. Results are discussed and some recommendations for updating the relevant standard are given in this work.

## 3.- Technical specifications and testing procedures

The UTSfSHS has been adapted to test the LED bulb quality according the following items:

*A.- Manufacturer documentation and visual inspection*

The information given by the manufacturer is important in order to obtain valuable information such as LED characterization information (in case it is possible to identify the model and the manufacturer and it has the IES-LM-80 test done) or electronic driver working capability (absolute maximum working values). See figure 1.

The recommended option is to use bulbs which have well defined LED devices with a well-defined and analyzed behavior, and a high quality manufacturing process that guarantee high energy efficiency and lumen maintenance and reliability.

*B.- Voltage operation range*

The LED bulbs must be tested on all the voltages that can be found on a SHS electric line. For 12 V LED bulbs, the range between 10 and 15 V. See figure 1.

*C.- Power consumption.*

The power consumption is calculated powering the LED lamp at 12 V. and measuring the current required. The value is taken after a 20 minutes stabilization process to guarantee stable values. See figure 1.

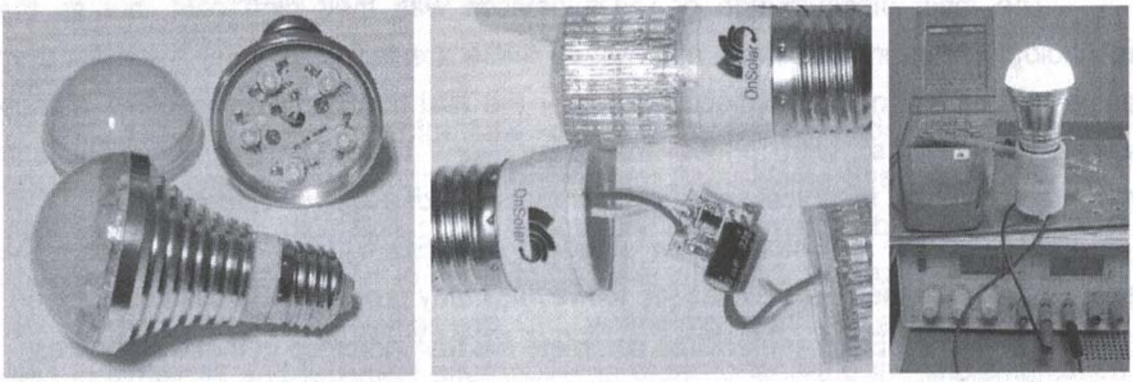

**Fig 1. LED bulb visual inspection and voltage and power operation range test.**

*D.- Light output and efficiency.*

To calculate the real lumens being emitted by the bulb lamps without using and integration sphere or a goniophotometer, we have used the same measurement equipment than the one proposed by Egido, et al. [5]. In this case from the Iluminance obtained from a lux meter and compared to the reference bulb it is possible to obtain its luminance. The error obtained with the lamps used on this work is always under a 5% error range. See figure 2.

Based on the state of the art, expected efficiencies are 60lm/W (compulsory), 80lm/W (recommended) and 100 lm/W (suggested).

*E.- Working temperature*

To reach the expected lifetime for LED devices, it is recommended no to overpass internal temperature values over 85ºC. According to different models of LED packages the thermal resistance can range from 5/10 ºC/W for high quality lighting LED to values over 30 ºC/W proper of non-lighting application devices. The working temperature of the lamp must be on the measured on the printed circuit board taken on established working mode (more than 20 minutes) on normal ambient conditions (25ºC) so that ambient temperature do not affect to the lamp thermal circuit. Good quality products must have values between 60-70 ºC (if they have power lighting LEDs (0.5 o 1 W packages) or between 50 and 60 ºC(if they have High

Brighness LEDs: 60mW or 20-40 LEDs/bulb). If the measure taken is below these values it indicates that the heat may not be properly being evacuated from the LED packages. If the measure is over that range the silicon crystal is over 85ºC and the reliability of the lamp in compromised.

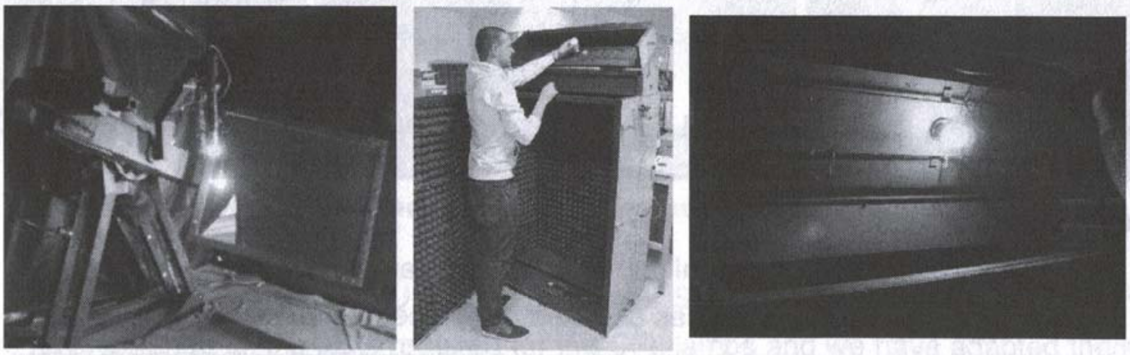

**Fig 2. Goniophotomer and black box iluminance test system.**

*F-Electrical and functional protection and EMIF quality*

The LED bulbs have been tested under the following risky situations:

- Inverted power polarization
- Power supply values over solar panel open circuit voltage
- Protection against humidity or insect entrance.
- Disconnection of any partial or mobile component
- Generation of EMIF on other electronic devices over the air or the electric line

*G.- Cycling endurance test.*

One of the main problems of the CFLs is the durability with repetitive turning on/off procedures. The electronic nature of LED lamp´s components foresees that this process is not relevant to their light emissions. However, it is necessary to verify that problems in the selection of the type of circuits or the power values or manufacturing fails does not makes of this point a failure possibility.

The recommended procedure to test this effect for CFL implies a time cycle distribution of 1 minute on and 2.5 minutes off. This period of time is required to ensure that the temperature of the lamp gets to the proper working values that may give different results depending on the ambient conditions. This cycle distribution makes that to complete a 10.000 cycles, a non-stop 1 month process is required.

As the temperature is not a relevant aspect to the turning on or off process of the LEDs and its electronics we have also performed a 10.000 cycles test but with a reduced cycle time distribution: 5 seconds on plus 5 seconds off. See figure 3.

*H.- Thermal endurance*

In this point, it is necessary to evaluate the behavior of the bulb not only in normalized ambient temperature but also on cold and warm situations, it will be analyses the turning on process, the working stability and change on behaviors on extreme ambient.

LED bulbs are tested on 5ºC, -10ºC and 50 ºC. As cold ambient temperature allows better light efficiency and lumen maintenance, it is only necessary to analyze the startup process on a wide operating voltage range. All the thermal test measures must be done without any forced ventilation system that may be acting over the LED so that the heat dissipater of the LED devices works on nominal mode. See figure 3.

## 4.- Testing results

After testing with this protocol all the LED bulbs obtained the main values and the field with incidences detected are presented on table I.

| BULB TYPE | Documentation | Working voltage | | | EMIF | | Protection | | | On/off Cycle | | Ambient Tª tests | | | Power | Efficiency | Thermal Analysis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Included | 10V | 12V | 15V | Air | Wire | Lack of IP | Inverse | Over Voltage | 5 s – 5s | 60 s – 150 s | 50 ºC | 5ºC | -10ºC | W @12V | lm/W @12V | Incidence |
| 1 | X | | | | | | X | | | | | | | | 3,3 | 61 | |
| 2 | X | | | | | | | | | | | | | | 3,6 | 48 | |
| 3 | X | | | | | | X | | | | | | | | 3,3 | 65 | |
| 4 | X | | | | | | | | | | | | | | 3,3 | 51 | X |
| 5 | | | | | | | | | | | | | | | 3,4 | 48 | |
| 6 | X | X | | | | | | | X | | | | X | X | 5,4 | 51 | X |
| 7 | X | | | | | | X | | | | | | | | 3,3 | 69 | |
| 8 | X | | | X | | | | | | | | X | X | X | 3,6 | 56 | |
| 9 | X | | | | | | | | X | | | | | | 5,8 | 36 | |
| 10 | | | | | | | | | | | | | | | 3,3 | 83 | |
| 11 | | | | | | | | | | | | | | | 3,3 | 90 | |
| 12 | | | | | | | | | X | | | | | | 5,6 | 80 | |
| 13 | | | | | | | | | X | | | | | | 5,4 | 88 | |
| 14 | | | | | | | | | | | | | | | 2,7 | 81 | |

**Table I. Resume of incidences and values obtained from the 14 LEDs bulb tested.**

## 5.- Conclusions

With the new LED lighting devices new possibilities are open for SHS. However, it is necessary to establish the required specifications and tests to evaluate the real functionality of any lighting device before using them on real projects in order to guarantee the robustness and the efficiency (electrical and luminous) of the lamps.

**Fig. 3. Cycling and Thermal endurance test procedures and verification**

Based on the existing Universal Technical Standard for Solar Home System we have adapted all the tests required for the CFL lamps and we have adapted them for LED bulbs using non sophisticated measure equipment.

We have checked the procedures, compared the results obtained with high tech equipment, and verified that the results obtained find the existing deficiencies on the lamps analyzed. On this process some existing test procedures have been redefined and new test procedures has been suggested, to evaluate specific important parameters that influence the LED activity (such as the device working temperature). The tests have been applied to a representative sample of LED bulbs and the results have been shown.

**References**

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[4] the Illuminating Engineering Society (IES) have developed the testing LED device standards LM-79 and LM-80 and Energy Star has developed the TM-21 guide to foresee the lumen maintenance of the semiconductor crystal over the time along with its current input and working temperature: Illuminating Engineering Society, 'IES LM-80-08 Measuring Lumen Maintenance of LED Light Sources', 2008. ISBN: 978-0-87995-227-3

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